Specification Amendments

On pages 2 and 3:

The design of segments for spherical shells and domes in the prior art will now be described in order to provide a background for the invention. A segment is meant to be a surficial portion of a shell, as contrasted to an underlying structural portion, although structural elements or capabilities may be incorporated within a physical segment. Physical segments designed for assembly of a sphere or dome have the same form as geometric segments obtained by division of the equivalent geometric figure, but may have additional features, such as attachment flanges for joining them together. For the present purpose, a geometric segment is any desired portion of a geometric figure and is a mathematical construct, while the physical segment is a useful article having the same general shape. ~~In many instances I will simply refer to a segment and the reader will be able to determine the type of segment.~~ Hereafter, the term, "segment," without a modifier shall refer to a physical segment that is joined to other segments by suitable attachment means to form a spherical shell or a dome. A mathematical element having a corresponding form will be referred to as a "geometric segment." The term, "segment," further implies a whole segment, one of several identical or nearly identical elements, except as specifically mentioned with regard to the prior art. Some whole segments may be cut through in making a dome or other portion of a full sphere or similar shell. Parts of segments formed by such cutting are referred to as partial segments or segment portions. The basic principles of designing segments will be illustrated by discussion of geometric divisions of spheres and regular polyhedra. Additional ~~features of physical~~ physical features of segments will be taught by later reference to specific examples and embodiments.

On page 4:

In mathematics, the division of surfaces into identical or repeating patterns of parts is referred to as tiling. Tiling, or segmentation, of the sphere has been investigated by many geometers, and artists such as M. C. Escher. Robert Dawson of Saint Mary's University, Halifax, Nova Scotia, has described many tilings of the sphere by isosceles triangles. Some of these tilings divide a sphere into more than 60 identical triangular geometric segments.

However, these geometric segments always have a long dimension of at least 60 degrees of arc which severely restricts their usefulness for manufacture of large objects.

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The number of segments used for this Berger half dome is 120, which exceeds the limit of 30 for domes having strictly identical segments (except as noted above for certain spherical triangles). Furthermore, Berger Brothers failed to achieve the higher level of uniformity that is possible with this degree of segmentation. As with Fuller's triangles, the Berger segmentation produced elements that were difficult to produce and assemble. In summary, prior efforts to segment the sphere have failed to realize the benefits of having identical, conveniently-shaped segments.

Spherical trigonometry is used for calculations on a sphere. Spherical figures such as spherical triangles or polygons are composed of angles and sides, the sides being great circle arcs. Great circle arcs are the spherical equivalents of line segments (see definitions). Arc lengths can be expressed either in angular measure or in conventional units of length. Often it is more convenient to express arc lengths in radians or degrees because definite numerical values can be given without knowing the radius of the sphere. Use of angular units for length is the usual practice in spherical trigonometry. Here, arc lengths are given in degrees when describing spherical segments. However, shipping dimensions, of length and with, for segments are straight-line dimensions and are given in meters (and feet). (See definitions for width of a segment.) A good source of additional reading on mathematical methods and formulas in spherical trigonometry is: Daniel Zwillinger, *CRC / Standard Mathematical Tables and Formulae.* Chapman & Hall /CRC, New York 2003.

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SUMMARY

According to the present invention, spherical and polyhedral shells are segmented in a manner that substantially improves cost and efficiency of manufacture. The ~~physical~~ segments are modeled after small, conveniently-shaped, oblong geometric segments of geometric figures. The wide range of applications will be illustrated by a few representative examples only.

Segments of a sphere are constructed by dividing a face of a spherical triacontahedron into quadrilateral segments, using lines running generally parallel to the sides of the face. In a preferred embodiment, one line is used to divide the spherical rhombic face into two identical oblong segments. This geometric segment form serves as a model for manufacture of ~~physical~~ segments that are useful for construction of spheres and domes in a variety of applications. Examples are pressurized storage tanks, light-weight greenhouses, and skylights. In other embodiments, my improved segmentations are used for assembly of spherical shells from any number of convenient oblong quadrilateral parts, and for manufacture of various polyhedral shells. The segments may include parts for convenient assembly or structural support

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Joining and Sealing of Segments—Figs. 4A to 5B

In order to assemble the ~~physical~~ segments into a useful structure, a method of joining them must be provided. A variety of joining means may be utilized, such as welding of metal shells, or use of flanges, clevis joints, or overlapping joints with suitable fasteners. Two examples of overlapping joints will be shown: use of underlapping flanges in Figs. 4A-C, and use of splicing and offsetting elements in Figs. 5A and 5B. Overlapping of segment edges is a method that is especially effective in developing the full strength capability of a shell. A well-secured overlapping connection provides very efficient transfer of all types of loads, such as tension, compression, shear, and moments.

Accordingly, the second embodiment shown in Figs. 4A-C, which depicts a ~~physical~~ quadrilateral segment 60 of the order discussed above, further incorporates joining means into the segment as underlapping flanges and means for their attachment. In Fig. 4A, flanges 62, 64, and 66 extend from the edges of the basic shape that was illustrated in the previous figures. Flange 62 extends outwardly from the lower half of the first long side and flanges 64 and 66 extend from the short sides. The flanges are generally beveled at the corners to avoid interference with other flanges from adjoining parts. The flanges are made to follow the spherical form of the segment and have top surfaces recessed sufficiently to mate in alignment with the undisplaced bottom surfaces of the overlapping edges of adjoining segments. This underlapping feature provides that the joints present minimum disruption on the exterior surface of the assembled structure.

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A spherically-curved dome roof of generally square appearance is shown in plan view in the embodiment of Fig. 13. This shell 200 is formed by joining together four groups of segments, each group together having the approximate form of a spherical square with sides having a length of 40 degrees of arc in this example. Square group 202 includes oblong segment 204, for example. The resulting assembly has a comparatively low height-to-width ratio, or aspect, of approximately 0.18 at the midsection. Due to the spherical curvature, the corners dip down much lower than the midsection edges, giving an aspect at the corners of approximately 0.34. This is the only embodiment to be presented in which the segmentation cannot be used to form a complete sphere or polyhedron. This fact lends more freedom in the segmentation plan, allowing reallocation of space so that all ~~physical~~ segments of the assembly are spherical rectangles of substantially identical size with least variation in overlap of edges.

On pages 11 to 14:

—Reference Numerals

20 sphere in Fig. 2A
22 great circle line of Fig. 2A and bottom edge of Fig. 2B
24 segment portion (small part) of Fig. 2B
25 segment portion (large part) of Fig. 2B
26 cut-off segment portion in Fig. 2A
27 remaining partial segment in Fig. 2A
28 partial segment in Fig. 2A
29 segment portion in Fig. 2A
30 segment (basic), and mirror image of segment 32 of Fig. 3B
32 segment (basic) of Fig. 3B, and mirror image of segment 30
34 side of spherical rhombic surface in Fig. 3C (first)
36 side of spherical rhombic surface in Fig. 3C (second)
38 side of spherical rhombic surface in Fig. 3C (third)
40 line of division (basic) and first long side of segments in Figs. 3A-3C
41 line perpendicular to both lines 38 and 42 in Fig. 3C

42 side of spherical rhombic surface in Fig. 3C (fourth)

44 first short side in Figs. 3A-3C

46 second short side in Figs. 3A-3C

48 first interior angle in Figs. 3A-3C

50 second interior angle in Figs. 3A-3C

52 third interior angle in Figs. 3A-3C

54 fourth interior angle in Figs. 3A-3C

56 flange, corresponding part of adjoining segment (upper) in Fig. 4B

58 flange, corresponding part of adjoining segment (lower) in Fig. 4B

60 physical quadrilateral segment of Figs. 4A and 4B

62 flange, extends outwardly from lower half of first long side

64 flange, extends from (upper) short side, and underlapping flange portion of Fig. 4C

66 flange, extends from (lower) short side of Figs. 4A and 4B

68 flange, same part (as 62) of mating segment of Fig. 4B

70 overlapping edge of an adjoining segment in Fig. 4C

72 fastener in Fig. 4C

74 optional adhesive placed along and between faying surfaces in Fig. 4C

76 exposed surface near overlapping line (segment 60) in Fig. 4C

77 overlapping line in Fig. 4C

78 exposed surface near overlapping line (mating segment) in Fig. 4C

80 insulated segment of Figs. 5A and 5B

84 inner shell segment in Fig. 5B

86 outer shell segment in Fig. 5B

87 short splicing-offset element in Fig. 5A

88 long splicing-offset element in Figs. 5A and 5B

90 insulation in Figs. 5A and 5B

92 female connector portion (first), left and top of Fig. 5A, and in Fig. 5B

93 female connector portion (second), at bottom of Fig. 5A

94 edge of outer shell segment 86 in Fig. 5B

96 edge of inner shell segment 84 in Fig. 5B

98 spacer in Fig. 5A

99 small void in Fig. 5A

100 spherical rhombic face assembled from four segments in Fig. 6

102 one of four segments of uniform crosswise section in Fig. 6

108 one of 36 segments in Fig. 7

110 spherical rhombus having 36 segments per 1/30th part of a sphere in Fig. 7

112 one of eight triangular faces in Fig. 8

114 line joining with line 116 to form first long side of oblong segments in Fig. 8

116 line joining with line 114 to form first long side of oblong segments in Fig. 8

118 center vertex in Fig. 8

120 segment, first of two equal parts formed by lines 114 and 116 in Fig. 8

122 line joining with line 124 to form second long side of segment 120 in Fig. 8

124 line joining with line 122 to form second long side of segment 120 in Fig. 8

126 first short side of segment 120 in Fig. 8

128 second short side of segment 120 in Fig. 8

130 segment, second of two equal parts formed by lines 114 and 116 in Fig. 8

132 line joining with line 134 to form the second long side of segment 130 in Fig. 8

134 line joining with line 132 to form the second long side of segment 130 in Fig. 8

136 first short side of segment 130 in Fig. 8

138 second short side of segment 130 in Fig. 8

140 segment comprising the right half of Fig. 9

142 rhombic face included in segment 140 of Fig. 9

150 middle segment of Fig. 10

154 corners of outside segments with interior angles measuring 72^{O} in Fig. 10

156 corners of outside segments with interior angles measuring 120^{O} in Fig. 10

158 half hexagon on top end of middle segment 150 in Fig. 10

160 side segment (two) in Fig. 10

162 half hexagon on bottom end of middle segment 150 in Fig. 10

164 half hexagons of side segments 160 in Fig. 10

170 segment of Fig. 11B

172 triangular tip, portion of segment 170 in Fig. 11B

174 first hexagon face of Figs. 11A and 11B

176 second hexagon face of Figs. 11A and 11B

178 pentagon face of Figs.11A and 11B

180 quadrilateral segment, one of the oblong faces of Fig. 12

182 first long side of quadrilateral 180 in Fig. 12

184 second long side of quadrilateral 180 in Fig. 12

186 first short side of quadrilateral 180 in Fig. 12

188 second short side of quadrilateral 180 in Fig. 12

190 first interior angle of quadrilateral 180 in Fig. 12

192 second interior angle of quadrilateral 180 in Fig. 12

194 third interior angle of quadrilateral 180 in Fig. 12

196 fourth interior angle of quadrilateral 180 in Fig. 12

198 spherical pentagon, one of the interstitial elements of Fig. 12

200 shell

202 square group, one-fourth part of shell 200 in Fig. 13

204 oblong segment in Fig. 13

P center point of the spherical rhombic surface

Wt top width of segment 30

Wb bottom width of segment 30

Wm right half of line 41 and middle width of segment 30

On page 20:

A first embodiment, representing my improved shell segmentation, is illustrated in Figs. 2A to 3C, and detailed by numeric examples in Table 1, and with accompanying descriptions. This is my improved shell segmentation in its simplest possible form, utilizing an oblong quadrilateral, 1/60th segment of a sphere without appurtenances. The quadrilateral is oblong in that it has adjacent sides of differing length; this is an underlying characteristic of my invention which will be present in all of the embodiments to be presented. Several variations of the basic form will be described.

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Figs. 3A and 3B illustrate that an ambiguity exists concerning mirror images. Both Figs. 3A and 3B show the division of a spherical rhombic face as described above, in the

simplest form of my improved segmentation, and together they illustrate a duality of possible segment shapes. The two figures show identical spherical rhombic faces that are convex upward (toward the reader) and with acute angles arranged vertically. Each figure shows a labeled segment with a first long side 40 near to parallel with a second long side 42, a first short side 44, and a second short side 46. The sides are connected in alternation, long to short, and then short to long, etc., to produce a segment with the approximate appearance of a parallelogram conformed to a sphere. The interior angles formed between the sides are first through fourth interior angles 48, 50, 52, and 54.

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Fig. 12 shows pentagons and quadrilaterals of approximately equal width. As in the first embodiment, quadrilateral 180 has a first long side 182, a second long side 184, a first short side 186, a second short side 188, and first through fourth interior angles 190, 192, 194, and 196. The segment is narrower and longer than in Figs. 2A-3C, but angles are comparable, with angle 192 measuring a little less than 72 degrees, angle 194 equal to 120 degrees, and the sum of angle 190 and angle 196 equaling 180 degrees. This segment also has nearly constant width, with variation comparable to that of the first embodiment. A continuum of quadrilateral dimensions, from those of the first embodiment to beyond this example, are achievable and within the scope of the invention.